ROLE OF MIMICS A CAD SOFTWARE IN 3D RECONSTRUCTION OF CT DATA IN ORAL AND MAXILLOFACIAL SURGERY.

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In partial fulfillment for the degree of

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BRANCH III

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CERTIFICATE

This is to certify that this dissertation titled **"ROLE OF MIMICS A CAD SOFTWARE IN 3D RECONSTRUCTION OF CT IN ORAL AND MAXILLOFACIAL SURGERY."** is a bonafide record of work done by **Dr. S. DANIEL SATHIYA SUNDARAM,** under our guidance and to our satisfaction during his postgraduate study period **2008-2011.**

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY, **in partial fulfillment for the award of the Degree of** MASTER OF DENTAL SURGERY– ORAL AND MAXILLOFACIAL SURGERY, BRANCH III **It has not been submitted (partial or full) for the award of any other degree or diploma.**

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Introduction

Aim and Objective

Review of Literature

Materials and Methods

Cases

Discussion

Conclusion

Bibliography

INTRODUCTION

Ever since radiations became a part of diagnosis after the discovery of X- rays by roentgen, it has undergone so many advances and the biggest leap of them all is the transition from 2D to 3D.

3D visualization and diagnosis has been made possible by computed tomography. With the arrival of 3D in radiography, the spectrum of use has widened in that it is not only being used for visualization, there is also use of the 3 dimensional images in diagnosing, treatment planning and surgical simulation which is now becoming a more popular method.[19,20]

Technological advances in computerized tomography (CT) have reduced time for data acquisition [22] and thereby reduce the exposure time and the radiation risk for the patient [22]. Now CT data can be exported in DICOM (Digital Imaging and Communication) format which is a format accepted universally by most of the softwares for reconstruction so that CT images may be economically and quickly generated using the CAD software. With Helical CT a single exposure is enough to obtain reconstructed images in all the 3 planes, Axial, Coronal and sagittal. 3D CT was judged superior to multiplanar two-dimensional CT

CT data can be exported into a CD in DICOM format. This data can be reconstructed into a 3D virtual object/model using various softwares. In our department Materialise Mimics is used for the reconstruction of CT data, visualizing, planning and surgical simulation.

Further the data can be exported in suitable format (*• STL) (standard triangulation language) for physical model fabrication with Rapid Prototyping technology. These models are accurate, can be fabricated with various different materials and they can be sterilized for intraoperative use.

CT data of patients is imported into the Mimics software and simulated for the following procedures.

1. Visualization analysis and Diagnosis
2. Virtual Treatment Planning and Surgical simulation
3. Physical Model for analysis, physical surgical simulation and template preparation.

3D computer-aided surgical simulation and model surgery provide accurate understanding, orientation to the underlying pathology for the students and young surgeons. Thus it reduces the intra operative surgical time and increases the accuracy and the efficacy of the surgery. Combination of virtual surgical simulation and stereolithographic models surgery can be validated as an effective method of preoperative planning for complicated maxillofacial surgery cases and also an effective teaching tool.[6,8,19,20,59]

AIM AND OBJECTIVE

The purpose of the study is to evaluate the efficacy of Mimics a medical based CAD software in 3D reconstruction of CT data, visualization, surgical simulation and physical model fabrication which can be used in Oral and Maxillofacial Surgery.

REVIEW OF LITERATURE

Noel G. Stoker 1992 [35] This literature says that the recent advancement of oral and maxillary surgery has produced the ability to surgically manipulate all of the components of the facial skeleton in concert or independently in all three dimensions. Diverse movements of individual components are difficult to visualize and the impact on facial form is inaccurately predicted. Particularly difficult to predict is the affect on the soft-tissue drape. Three-dimensional imaging provides significant advantages, because appreciation of the deformity in every plane is possible. Three-dimensional computer graphics allows the clinician to manipulate various components and analyze the resulting changes in facial harmony. Soft-tissue contours can be evaluated for symmetry and esthetics. Prediction and planning of precise movements of the skeletal parts is greatly aided by the creation of an exact model. Solid models created by CAD systems from CT data are of considerable assistance, and are used for planning by a number of disciplines and surgical specialties. Accurate prosthetic devices can be produced in the laboratory, thus minimizing operating time. In addition, this article also states that the surgeon has accurate mental images of the anatomy that will be encountered.

M. Wehmdller 1995 [16] This article explains about the feasibility and the reduced cost of the CAD objects. In the past an economic fabrication of individual prostheses used in reconstructive cranio-maxillo-facial surgery was not possible due to technical deficiencies. Now, through the consistent use of the most modern computer-based techniques developed in the field of industrial engineering, these costs can be reduced to an economic level. Mathematical freeform surfaces models are first created from helical computed tomography data. These serve as the basis for an efficient and idealized construction of prostheses geometries, and provide control- data for a computerized numerical control-fabrication. In 4 clinical cases this new processing technique has successfully been utilized in the fabrication of individually designed prostheses for the reconstruction of skull defects. The range of opportunities offered is reflected not only in the great variety of possible geometric details, but also in the fact that the prostheses may be manufactured partly using indirect impression-taking techniques from 3 different biocompatible materials so far and other applications are likely to turn up.

S. Girod 1995 [46] This article proposes a new system which will allow a precise preoperative visualization of not only bony structures but also the soft tissue surfaces. 3D CT data of the skull are integrated with 3D surface data acquired by laser scanning. Based on the 3D CT data the bony structures are segmented automatically and processed interactively to simulate the planned surgical procedure. Afterwards, the 3D soft tissue changes resulting from the shifting of bony segments are computed. The postoperative appearance of the patient is visualized using computer animation techniques.

B. Luka 1995 [5] This article states that spiral CT is superior to the conventional single slice CT in that it can reconstruct slices in all the three planes axial, coronal and sagital in a single exposure, and also there is no need of repositioning the patient from supine to prone positions which is also not possible in a polytraumatised patient. Hence 3D reconstructions from a spiral CT are a better option than the conventional single slice CT.

J. S. Bill 1995 [18] This article talks about the use of Steredlithography (STL) as a method of organ-model-production based on computed tomography scans which enables the representation of complex 3-dimensional anatomical structures. Surfaces and internal structures of organs can be produced by polymerization of UV sesnsitive liquid resin using a laserbeam. In oral and maxillofacial surgery this technique is advantageous for reconstruction of severe skull defects because a more accurate preoperative planning is possible. Using recently developed software it is possible to reconstruct unilateral bony defects by virtual mirror imaging of the contralateral side and production of a STL mirror model as well as the reconstruction of non-mirrorable defects by superposition. Advantages of STL are the representation of complex anatomical structures, high precision and accuracy, and the option to sterilize the models for intraoperative use. More accurate planning using this method improves postoperative results, decreases risks and shortens treatment time.

H. Eufinger 1995 [16] Computer aided design and manufacturing (CAD/CAM)-techniques based on helical computed tomography (CT) data are successfully used for the prefabrication of prostheses: An individual computer based 3-dimensional model of the bony defect is generated after acquisition, transfer and evaluation of the CT data; from this freeform surfaces geometry an individual and "idealized" prosthesis-geometry is derived and fabricated by a numerically controlled milling machine using modern industrial CAD/CAM-systems and design software. The margins of this prosthesis-geometry are generated by the borders of the defect and the surface by considering the non-affected neighboring contours.

William palm 1998 [58] This literature gives a review of the process involved in the making of rapid prototyping, the different techniques, and materials for acquiring a rapid prototype model.

Xia J 2000 [59] Five major functions of 3D CT reconstruction CAD software are given in this article they are: post-processing and reconstruction of computed tomographic (CT) data, transformation of 3D unique coordinate system geometry, generation of 3D color facial soft tissue models, virtual surgical planning and simulation, and presurgical prediction of soft tissue changes. The basic measuring functions, such as linear and spatial measurements, are also included. The surgical planning and simulation are based on 3D CT reconstructions, whereas soft tissue prediction is based on an individualized, texture mapped, color facial soft tissue model. The surgeon "enters" the virtual operatory with virtual reality equipment, "holds" a virtual scalpel, and "operates" on a virtual patient to accomplish actual surgical planning, simulation of the surgical procedure, and prediction of soft tissue changes before surgery. As a final result, a quantitative osteotomy-simulated bone model and predicted color facial model with photorealistic quality can be visualized from any arbitrary viewing point in a personal computer system. This system can be installed in any hospital for daily use.

J. Xia 2000 [19] The use of 3D CT in virtual surgery and planning is highlighted in this article. The surgeon immerses in a virtual reality environment with stereo eyewear, holds a virtual "scalpel" 3D Mouse and operates on a "real" patient 3D visualization to obtain pre-surgical prediction 3D bony segment movements. Virtual surgery on a computer-generated 3D head model is simulated and can be visualized from any arbitrary viewing point in a personal computer system.

Gateno J 2000 [14] This study is to show that planning distraction osteogenisis and the prediction of the surgical outcome with the help of virtual distractors and virtual surgery is accurate. Virtual surgery was done on a 3D CT reconstruction and prediction done. The same surgery was done on the RP model taken from the CT. The distractors were placed in the same position as in the virtual surgery using a splint taken from the virtual model. The outcome of distraction in the RP model was the same as virtual surgery.

Papadopoulos MA 2002 [37] Three-dimensional imaging techniques provide extensive possibilities for the detailed and precise analysis of the whole craniofacial complex, for virtual (on-screen) simulation and real simulation of orthognathic surgery cases on biomodels before treatment, as well as for the detailed evaluation of the effects of treatment. Laser scanning in combination with the stereolithographic biomodeling seems to be a very promising combination for three-dimensional imaging, although there is still considerable room for improvement. Constant efforts should be made in the direction of developing and enhancing the existing techniques as well as exploring the potential for developing new methods based on emerging sectors of technology.

U. Meyer 2002 [56] This article states that in contrast to the evaluation of classic two dimensional cephalometric radiographs, analysis of three-dimensional images did not suffer from superposition of all structures on a plain film and different enlargement factors according to the distance from the radiographed structures to the X-ray tube. Therefore, simulation of craniofacial deformities on the basis of CT data was used to increase the accuracy of the planned treatment protocols. The use of three-dimensional imaging allowed topographical evaluation of all craniomaxillofacial deformities. Improvements in standard computer technology enabled time-efficient virtual operations.

L. Vrielinck 2003 [27] This article presents and validates a planning system for implant insertion based on preoperative CT imaging. It allows the surgeon to determine the desired position of different kinds of implants. Finally a customized drill guide is produced by stereolithography. In this study, zygoma, pterygoid and regular platform implants were used. The treatment protocol is validated through 12 case studies, selected at random from the total patient group. From postoperative images, the exact implant location is determined and the deviation of axes between planned and inserted implants is calculated. In this *in vivo* study, displacements, varying according to the type of implant and the location of the implants, were observed. From a clinical standpoint, most of the inserted implants were judged to be adequately sited. A prospective clinical follow-up study was performed on all 29 patients. Although all patients presented with severe maxillary atrophy, excellent cumulative survival rates (92%) for the zygoma implants and 93% for regular platform implants have been obtained.

T. Sohmura 2004 [55] Training of the surgeons on delicate procedures has been made easy by constructing a 3D model from CT data. A new system called haptic system has been used which also gives the feel and pressure felt during performing surgeries. This device allows operators to experience and train in delicate manual surgical operations and this system to train implantologists in bone boring. The change in resistance between compact bone and cancellous bone can be experienced virtually.

Federico Cesarani 2004 [11] CT's were taken for Egyptian mummies and without removing their bandages, and skull and soft tissue reconstruction were done for them. This article lays emphasis on role of the 3D reconstruction of CT, in forensic department.

Jon D. Wagner 2004 [23] This article talks in depth about the use of rapid prototype model in physical model surgery and prefabrication of plates on the physical model. The most time-consuming steps in the surgical repair of fractures are the establishment of proper occlusion through intermaxillary fixation before reduction of the fractures and the contouring of rigid reconstruction plates used to secure the aligned mandibular segments. The surgical time required for reduction of fractures and contouring of plates may be lessened by presurgical planning based on the use of models of the maxillofacial region made by rapid 3-dimensional 3D prototyping. The new technique generates detailed models of the craniofacial region within hours at nominal cost using a compact hospital-based printer. Surgeons can now use 3D models to replicate fracture lines, to reduce the replicated fractures, and to contour reconstruction plates before surgery for acute maxillofacial trauma. The plates not only serve to stabilize fractures but also act as templates for the reduction of fractures during surgery. Furthermore, the difficult task of contouring rigid reconstruction plates is accomplished accurately during presurgical planning and not during surgery when visualization of the fracture site is obscured by soft tissue and the complete perspective of the repaired mandible is not evident. This enhances the accuracy of reconstruction and significantly decreases the surgical time required to repair a fracture.

M. Y. Hajeer 2004 [34] This article claims that the storage of dental casts need a larger space in a hospital, but if the casts are stored in a digital format, after laser scanning or CT, they can be converted into digital format and stored in a CD which requires a smaller space and communication between professionals can be easier.

R. Ewers 2005 [40] Basic research and routine clinical application of computer-aided navigation technology conducted over the past 10 years have proved that the application of this technology offers essential improvement in outcome and intraoperative safety in a wide range of craniomaxillofacial procedures.

A. Rachmiel 2005 [2] The article describes about the method of mandibular distraction osteogenesis in order to improve airway to respiratory distressed patients due to significant mandibular deficiency, and to present the quantitative volumetric evaluation of mandible and upper airway using three-dimensional-CT ,3D-CT before and after distraction. This study involves 12 patients aged 12 months to seven years with various complaints of Obstructive Sleep Apnea OSA such as noisy breathing during sleep, waking episodes, pauses in respiration and daytime somnolence. All the patients underwent bilateral mandibular distraction under general anesthesia. 3D-CT of face and neck is performed before and after distraction and a quantitative volumetric evaluation of mandibular volume and airway volume is performed.

Kapil Saigal 2005 [24] The 3D reconstructions created using 1- or 2-mm axial source images are detailed enough to show nondisplaced fractures. 3D reconstructed CT scans were interpreted more rapidly and more accurately by clinicians and that 3D CT was more accurate at assessing zygomatic fractures but was inferior to axial images for evaluating orbital fractures. 3D reformatting of a 2D CT recreates the surgeon's complex mental process of visualizing fractures in operative planning. Disadvantages of the technique include the potential introduction of artifacts resulting in reformatting errors and the inability to represent soft tissue structures.

G. R. J. Swennen 2005 [12] This article presents a new method for objective assessment of the distraction regenerate using three-dimensional quantitative computer tomography (3D-QCT). The distraction specimens of 16 sheep that underwent bifocal cranial distraction osteogenesis to reconstruct a critical size defect were used to evaluate this method. To analyze the validity of this method the results were compared to conventional quantitative computer tomography. Method comparison according to Bland-Altman showed that three-dimensional computer tomography based bone densitometry is valid for future DO research.

C. d'Hauthuille 2005 [8] Comparison between computer assisted surgery and surgical planning with rapid prototyping model using MIMICS has been done for distraction osteogenisis and the article claims that the group who were planned with RP model had a better outcome.

Y. Tsuji 2005 [62] Bilateral sagittsal split osteotomy cuts were planned after visualizing the relation of the inferior alveolar nerve to the cortices of the mandible through a CAD software. The software used to identify the course of the inferior alveolar nerve.

T.G. Kwon 2005 [53] This study intended to evaluate the morphological characteristics of the cranial base and maxillomandibular structures of facial asymmetry in adult patients, so as to determine whether mandibular asymmetry is a result of primary mandibular deformity or if it is influenced by cranial base deformity They were compared with three-dimensional 3D CT reformatted images using a 3D visualization and analyzing program. The differences between the two groups, the correlation between the cranial base and maxillomandibular asymmetry were evaluated statistically.

Yeshwant K 2005 [64] In this study preoperative CT scans from 15 patients with symmetric and asymmetric deformities were imported into a CT-based software program. The software was used to reconstruct virtual 3-dimensional models from these scans. Two experienced surgeons, working with a computer scientist, then used Osteoplan to create an ideal treatment plan for each patient. In each case, the 3-dimensional curvilinear movement was quantified using 4 parameters of movement. These parameters were then used to prescribe a distraction device capable of executing the planned skeletal correction. Curvilinear distractor dimensions calculated by Osteoplan included the radius of curvature of the prescribed device, and the distractor elongation, pitch, and handedness. Treatment plans including POMs were developed for each patient. The results of this study indicate that, using geometric parameters of movement calculated from 3-dimensional CT scans, curvilinear devices could be prescribed for correction of the range of skeletal deformities in this group of patients.

John Winder 2005 [21] This article talks about various techniques available materials for production of a physical model. It also talks about the limitations and how to overcome the minor faults in obtaining a physical model.

Xia JJ 2006 [61] The purpose of this study is to assess the costs and benefits of computer-aided surgical simulation (CASS) and to compare it with the current surgical planning methods for complex cranio-maxillofacial (CMF) surgery. Any great new design should consist of at least 2 of the 3 following features: faster, cheaper, and better outcome. This analysis demonstrates that CASS is faster and less costly than the current standard planning methods for complex CMF surgery. Previous studies have also shown that CASS results in better surgical outcomes. Thus, in all regards, CASS appears to be at least as good as the current methods of surgical planning.

Alexander Schramm 2006 [4] This article claims that in craniomaxillofacial surgery, advances in imaging techniques spiral-CT, 3D-imaging and associated technologies stereolithographic models, CAD_CAM have led to improved preoperative planning within the past years. Stereolithography models are suitable to resemble the actual situation of the patient three dimensional situation of hard tissue defects and allow to some degree pre or intraoperative manufacturing of individual prostheses; they do not fulfill all the requirements for craniomaxillofacial plastic and reconstructive procedures i.e. preoperative planning with virtual correction, intraoperative navigation and postoperative control. Stereolithographic models resemble just one given situation within the greyscale of the acquired spiral-CT data set. They always imply the mistake of “pseudoforamina” in thin bony structures, which are widely presnt in the peri- orbital region.

B. Vikraman 2007 [6] This article gives all the uses of a CAD based medical software, and that now this technology is indispensible in surgery department. The article says it useful to visualize, plan the treatment and perform surgical simulations using MIMICS software.

A.C. Sekar 2007 [1] This literature says that cephelometric analysis can be done in 3D which is more accurate than the conventional 2D lateral cephelometric analysis.

Caloss R 2007 [9] This article says that conventional two-dimensional imaging for assessing and treatment planning orthognathic surgery has limitations. Three dimensional imaging offers the ability to more accurately portray maxillofacial anatomy. Three-dimensional CT-based models can be generated for assessment of the dentofacial deformity. Interactive software can simulate surgical moves and algorithms can predict the three-dimensional soft tissue changes that will occur. This will inevitably affect diagnosis and treatment planning for orthognathic surgery in the future.

Metzger MC 2007 [32] This article tells that preoperative creation of virtual models by segmentation of the computerized tomography CT dataset and mirroring of the unaffected side allows for precise planning of complex reconstructive procedures. The preoperative CT dataset including the virtual planning and the postoperative CT dataset were compared by using image fusion. No differences between the skull and face symmetry were found according to this study.

Xia JJ 2007 [60] Current surgical planning methods are usually not adequate for the treatment of patients with complex craniomaxillofacial deformities. This article says that the authors have developed a 3-dimensional computer-aided surgical simulation planning method for the treatment of patients with complex CMF deformities. The purpose of this pilot study is to evaluate the accuracy of this technique in the treatment of patients with complex CMF deformities. Five patients with complex CMF deformities were enrolled. Surgeries were planned with the CASS planning method. Surgical plans were transferred to patients at the time of surgery via computer-generated splints. After surgery, outcome evaluation was completed by first superimposing the postoperative computed tomography CT model onto the planned model, and then measuring the differences between planned and actual outcomes.

Pham AM 2007 [38] Recent advances in computer-modeling software allow reconstruction of facial symmetry in a virtual environment. This study evaluates the use of preoperative computer modeling and intraoperative navigation to guide reconstruction of the maxillofacial skeleton. Three patients with traumatic maxillofacial deformities received preoperative, thin-cut axial CT scans. Three-dimensional reconstructions, virtual osteotomies, and bony reductions were performed using MIMICS planning software (Materialise, Ann Arbor, MI). The original and "repaired" virtual datasets were then imported into an intraoperative navigation system and used to guide the surgical repair. Postoperative CT scans and photographs reveal excellent correction of enophthalmos to within 1 mm in patient 1, significant improvement in symmetry of the nasoethmoid complex in patient 2, and reconstruction of the zygomaticomaxillary complex location to within 1 mm in patient. Computer modeling and intraoperative navigation is a relatively new tool that can assist surgeons with reconstruction of the maxillofacial skeleton.

Stephan Jacobs 2008 [49] This article gives the use of 3D reconstruction in Cardiac surgery. Based on computer tomography (CT) and magnetic resonance imaging (MRI) images, regions of interest were segmented using the MIMICS 9.0 software. The segmented regions were the target volume and structures at risk. After generating an STL-file out of the patient's data set, a 3D plaster model was created. The patient individual 3D printed RPT-models were used to plan the resection of a left ventricular aneurysm and right ventricular tumor. The surgeon was able to identify risk structures, assess the ideal resection lines and determine the residual shape after a reconstructive procedure (LV remodelling, infiltrating tumor resection). Using a 3D-print of the LV-aneurysm, reshaping of the left ventricle ensuring sufficient LV volume was easily accomplished. The use of the 3D rapid prototyping model (RPT-model) during resection of ventricular aneurysm and malignant cardiac tumors may facilitate the surgical procedure due to better planning and improved orientation.

Noortje I. Regensburg 2008 [36] MIMICS Materialise is a valuable tool for the calculations of orbital soft tissue volume. Because it can be used on any stack of images, comparisons of CT scans and MRI scans are possible. Intraobserver variability was less than 5% for the calculations of Fat Volume, Muscle Volume, and Bony Orbital Volume. Interobserver variability did improve with better knowledge of anatomy and strict adherence to the segmentation protocol.

Khemachit Sena 2008 [27] MIMICS Meterialise is used according to this article to evaluate the average measurements of the Thai skulls. This was done to produce standardized skull implants for Thai patients. This prevents CT procedure for all the patients as the implants are prefabricated.

Bell RB 2009 [7] This article deals with the most common problem faced in reconstruction of Post-traumatic or postablative enophthalmos and diplopia and/or facial asymmetry resulting from inaccurate restoration of orbital anatomy remain relatively frequent sequellae of complex orbital reconstruction. Recently, preoperative computer-assisted planning with virtual correction and construction of stereolithographic models have been combined with intraoperative navigation in an attempt to more accurately reconstruct the bony orbit and optimize treatment outcomes. Anatomic restoration of internal and external orbital contours was obtained in all but 1 patient based on a comparison of preoperative and postoperative CT scans. Further evaluation of the postoperative CT images compared favorably to the virtually planned reconstructions. Despite favorable restoration of internal and external bony anatomy, the soft-tissue limitations were not completely overcome in some patients with secondary deformities.

Li WZ 2009 [29] This article provides information about the use of MIMICS a CAD based medical software in surgical treatment of trauma patient. For a Zygomatico-facial collapse deformity resulting from a zygomatico-orbito-maxillary complex (ZOMC) fracture, CT scan data are processed for three-dimensional (3D) reconstruction. The reduction design is aided by 3D virtual imaging and the 3D skull model is reproduced using the RP technique. In line with the design by Mimics, presurgery is performed on the 3D skull model and the semi-coronal incision is taken for reduction of ZOMC fracture, based on the outcome from the presurgery. Postoperative CT and images reveales significantly modified zygomatic collapse and zygomatic arch rise and well-modified facial symmetry. The CAD/CAM and RP technique is a relatively useful tool that can assist surgeons with reconstruction of the maxillofacial skeleton, especially in repairs of ZOMC fracture.

Altan Varol 2009 [3] The article gives the results of a study in which Maxillary distraction osteogenisis was planed for five patients with maxillary retrognathism. All the patients were planned with MIMICS 10.01 CMF and Simplant 10.01 software. Distraction vectors and rods of distractors were arranged in 3D environment and on STL models. All patients were operated under general anaesthesia and complete Le Fort I downfracture was performed. All distractions were performed according to orientated vectors. All patients achieved stable occlusion and satisfactory aesthetic outcome at the end of the treatment period. Preoperative bending of internal maxillary distractors prevents significant loss of operation time. 3D computer-aided surgical simulation and model surgery provide accurate orientation of distraction vectors for premaxillary and internal trans sinusoidal maxillary distraction. The author concludes saying that a combination of virtual surgical simulation and stereolithographic models surgery can be validated as an effective method of preoperative planning for complicated maxillofacial surgery cases.

Swennen GR 2009 [51] This article describes the different stages of the workflow process for routine 3D virtual treatment planning of orthognathic surgery: 1) image acquisition for 3D virtual orthognathic surgery; 2) processing of acquired image data toward a 3D virtual augmented model of the patient's head; 3) 3D virtual diagnosis of the patient; 4) 3D virtual treatment planning of orthognathic surgery; 5) 3D virtual treatment planning communication; 6) 3D splint manufacturing; 7) 3D virtual treatment planning transfer to the operating room; and 8) 3D virtual treatment outcome evaluation. The potential benefits and actual limits of an integrated 3D virtual approach for the treatment of the patient with a maxillofacial deformity are discussed comprehensively from our experience using 3D virtual treatment planning clinically.

M. Chizari 2009 [33] This literature gives a review on how 3D CT was used to reconstruct a knee and by finite element analysis its loading.

Yanpu Liu 2009 [63] This article talks about mirror imaging which is a very useful tool in reconstructive surgical planning and as well as surgery. The advantage of using this new method is the pre-surgical planning using the rapid prototyping model to help us understand the three-dimensional deformity of the patient. Mirror imaging permitted exact symmetrical bony reconstruction. However, the technique does have some disadvantages. Deviation can take place during transfer of the data and during the rapid prototyping. However, the most serious inaccuracy happens when the implant is being sculpted by the surgeon's hands during the operation. The result therefore depends on the surgeon's skill and talent. This article also says that if there was a compactable biomaterial that could be fabricated immediately using rapid prototyping, the corrective operation would be easier, and a more accurate facial contour could be obtained.

Philipp Juergens 2009 [39] This article is a study about the use of rapid prototype model for reconstruction of mandible, with a reconstruction plate, where it is pre adapted and then fixed intraoperatively. This reduces this time of surgery and eliminates the need for intra operative bending of the reconstruction plate.

Wesam Aleid 2009 [57] This article explains how rapid prototype model can be made inhouse, MIMICS software has been used make 3D virtual models and obtained as physical models and says it is worth spending money on installing this machine for each department. It says the machines print head expels a binding solution on to a powder surface, then moves down a layer and new powder is distributed. The layers are built up in this way to make a solid three-dimensional model. Powder that is not used supports the structure so no additional supports are necessary and it is later vacuumed away to expose the surface of the model. This reduces waste and time spent cleaning the model. The model is porous and different binding solutions can be added to create different properties.

Collyer J 2010 [10] This article states that it is potentially useful in any procedure where it is possible to make a three-dimensional surgical plan from computed tomography (CT). 3D CT and reconstruction, and virtual planning is more useful in secondary orbital reconstruction in oral and maxilla facial surgery.

Tang W 2010 [52] This article shows that orbital wall fractures can be diagnosed in early fracture stages and that the degree of long-term enophthalmos can be predicted with 3-Dimensional Medical Surface Rendering software. This article's results suggest that early-stage orbital wall fractures should recover Orbital volume as early as possible, and that advanced stage orbital wall fractures should overcorrect OV. The degree of accuracy and rational of OV reconstruction can be improved by appropriate individual digitalization design and rapid prototyping technology.

S Padmanabhan 2010 [47] This article shows that CT measurements did not show a significant difference from the direct skull measurements in all three planes except for two midsagittal measurements in the anteroposterior plane. Cephalometric measurements were comparable to direct skull measurements for midsagittal measurements in the anteroposterior plane, but showed a significant difference when bilateral measurements were considered. Cephalometric measurements also showed a significant difference in the transverse plane from direct measurements and CT measurements; however, they did not display a significant difference between direct skull measurements and CT measurements for most parameters in the vertical plane. Linear measurements on the spiral CT were comparable to anatomical measurements and were more reliable than cephalometric measurements. Cephalometric measurements were acceptable for midsagittal measurements in the anteroposterior plane, but showed a significant variation from anatomical and CT measurements in most other parameters.

Gary Orentlicher 2010 [13] This article gives a broad outline of the various uses of 3D reconstruction and the medical based CAD software. It talks about drawing nerve and measuring its proximity to third molar or to the planned osteotomy cuts. It also says that the precision, accuracy, and 3-dimensional visualization capabilities of these technologies open avenues for the oral and maxillofacial surgeon in the diagnosis, planning, and surgical management and the combination of these technologies is useful in expanding our information in dentoalveolar, preprosthetic, trauma, pathology and reconstruction, orthognathic and craniofacial, and cosmetic esthetic implant surgical cases. This article discusses the use of these technologies in the practice of oral and maxillofacial surgery.

T. Shirota 2010 [54] The purpose of this article is to measure the bone volume necessary for secondary bone grafting in the alveolar cleft using surgical simulation software based on three-dimensional computed tomography (CT) scan data, to compare this measurement with the actual volume of the bone graft, and to evaluate consistency. The patients with cleft lip and palate undergo CT using a cone-beam CT unit (CB-CT) 1 month before surgery, followed by bone grafting with particulate cancellous bone and marrow (PCBM) to close the cleft. The bone volume necessary for grafting is measured based on the CB-CT scan data. This article suggest that measuring and preoperatively calculating the bone volume necessary for bone grafting with surgical simulation software using CB-CT scan data is beneficial.

Scott Tucker 2010 [48] This article talks about a study which was conducted to determine whether the virtual surgery performed on 3D models constructed from cone-beam computed tomography (CBCT) can correctly simulate the actual surgical outcome and to validate the ability of this emerging technology to recreate the orthognathic surgery hard tissue movements in 3 translational and 3 rotational planes of space. The article gives a conclusion that the pre operative prediction model and the actual post operative model showed no significant difference and thus the surgical planning and prediction are reliable.

Li-bin Zhou 2010 [30] This article mentions about planning of surgery for hemifacial microsomia. The application of CAD software and RP model facilitate the accurate design of individual prostheses for mandibular defects. Facial symmetry is restored with the help of the mirror imaging technique during CAD. Moreover, the use of these techniques helps to reduce the operating time and eliminate operation errors. Some errors can occur during the data transfer, model construction, and tray casting; however, it is far more accurate than manually bending the reconstruction plate and shaping the fibula intraoperatively.

R. Olszewski 2010 [41] In this article the authors present a new procedure of computer-assisted genioplasty. They determined the anterior, posterior and inferior limits of the chin in relation to the skull and face with the newly developed and validated three-dimensional cephalometric planar analysis ACRO 3D. Virtual planning of the osteotomy lines was carried out with MIMICS Materialize software. The authors built a three dimensional rapid-prototyping multi-position model of the chin area from a medical low-dose CT scan. The transfer of virtual information to the operating room consisted of two elements. First, the titanium plates on the 3D RP model were prebent. Second, a surgical guide for the transfer of the osteotomy lines and the positions of the screws to the operating room was manufactured. The postoperative results are promising, and the technique is fast and easy-to-use.

MATERIALS AND METHOD

This study was done in the department of Oral and MaxilloFacial Surgery, Ragas Dental College and Hospital, Uthandi, Chennai.

Period of study was done during September 2008 to July 2010.

CT was taken for selective patients

A CAD based medical software MIMICS (Materialise, Leuven, Belgium.)is used for 3D reconstruction of the acquired CT data.

CT protocol.

CT Scan parameter for all the patients were as follows,

Vertex to Manubrium,

130 kV and 81 mA/s,

Slice increment 0.5mm,

Width 512 pxl,

Height 512 pxl,

Pixel size .500 mm,

Gantry tilt 0.00,

Algorithm H70s.

Visualization and Diagnosis

Visualization of fracture site, displacement of fractured segments was done in trauma.

Extent and involvement of surrounding structures was visualized for tumor.

Cephelometric analysis was done for orthognathic cases and the values were used for diagnosis of the condition.

Treatment planning and Surgical Simulation.

Fracture segments were virtually manipulated and reduced and the nature of reduction required was planned.

Virtual surgery was done as planned and thereby the osteotomy sites were decided, repositioning of the osteotomised segment was planned and hard tissue and soft tissue changes were predicted.

In cases for whom BSSRO was planned distance of the inferior alveolar nerve from the outer cortex, base of the mandible and from the alveolus was measured and BSSO cut was oriented in relation to the nerve.

Extent of resection was planned and virtual surgery was done in the virtual model for tumor.

Physical model- Analysis, Surgical simulation and Templates.

In trauma cases physical model was made and the reduction of the fractured segments was done.

The plates used to fix the fragments were adapted on the reduced fracture sites on the physical model and later the same plates were sterilized and used intraoperatively.

In orthognathic surgery cases, the planned osteotomies were done on the physical model and the desired result was obtained on the physical model and the same osteotomies were performed intraoperatively.

In tumor, as mock surgery, resection was done on the physical model

The reconstruction plate that would be used was adapted over the Physical model and the same plate was sterilized and used intraoperatively.

CASE HISTORY FORMAT

Name –

Age /sex –

Address –

Chief complaint –

History of presenting illness –

Past Medical History –

Vomited after the injury –

General examination –

Temperature -

BP –

RR –

Pulse -

Level of conciousness – Eye-, Motor-, Verbal-.

Aneamia –

Cerebral irritation –

Neck stiffness –

Sensory loss –

Pupil size –

Cornea –

Diplopia –

Maxillo facial signs –

Contour defect –

Orbit –

Oral examination 87654321 | 12345678

87654321 | 12345678

Occlusion –

Mouth opening –

Provisional diagnosis

Investigations – blood group, Hb, TC, DC, RBS, ESR, CT/BT, HBs Ag, HIV

Radiological investigations –

For orthognathic cases facial esthetic values are recorded.

For pathology, inspection and palpation findings are recorded.

CASES

Case 1

A patient named Nazeer Ahmed 34/M came with complaints of depression in the right side cheek and inability to open the mouth normally, and he gave a history of cricket ball injury one month back. His vitals were stable and his mouth opening was 17 mm between 11 and 41.

A complete history was taken; blood investigations and radiographs were taken.

Submento vertex revealed there was a zygomatic arch depression.

There were no other findings in other radiographs.

CT was taken according to the protocols and imported into MIMICS software. The fracture sites were visualized. The nature of displacement of the fractured segments were visualized which helped in the treatment planning.

Case 2

A patient named Solai malar, 23 years of age came to the department with complaints of backwardly placed lower jaw from her young age.

A complete case history was taken and blood investigations, radiographic investigations were also done.

A CT was taken and imported into MIMICS and treatment planning was done based on lateral cephelometric analysis which was done in the reconstructed 3D virtual model based on burrstone values for both hard and soft tissue.

This helped in diagnosis and treatment planning.

Case 3

A patient named Purusothaman 23/M came with complaints of forwardly placed lower jaw.

A complete case history was taken and blood and radiographic investigations were done.

Cephelometric analysis was done and mock model surgery was done.

Maxillary Lefort 1 advancement with Bilateral saggital split ossteotomy was planned to correct maxillary deficiency.

Virtual surgery was performed in the virtual 3D model

Nerve evaluation in relation to the BSSRO cuts was done to accurately measure the proximity of the nerve to the osteotomy and the cuts were planned accordingly.

Case 4

A patient named karthikeyan 21/M came with complaints of swelling of the palate in the left side which started as a small swelling three months back and increased in size.

Case history was taken and clinical examination and blood investigations were done.

Biopsy was done specimen was sent for pathology and reported as mucoepidermoid carcinoma of left maxillary sinus.

Radiograph was of little use as it did not give clear view of the margins and involvement of the pathology.

CT was taken and the data was imported into MIMICS software and 3D virtual model was reconstructed.

CT data showed clearly the margins of the pathology and the involvement of the surrounding structures was visualized.

Virtual surgical simulation of resecting the pathology was done, the approach to the site and the surrounding structures to be spared was clearly visualized, this helped in easy identification of the tumor margin and to resect in toto the pathology intraoperatively and reduced the operative time.

Case 5

A patient named chandrasekar 31 /M came with complaints of pain and swelling in the left side of the face, inability to open the mouth and numbness in the upper lip region for the past 4 days. He gave a history of fall from his bicycle during which he sustained the injury and developed the above said complaints.

A complete case history was taken, blood investigations and radiographs were taken.

Sub Mento vertex revealed zygomatic arch fracture and PA cephelogram revealed orbital rim fracture. But the radiographs were not clearly descriptive and so CT meeting the previously mentioned protocol was taken.

CT data was converted into DICOM format exported into CD and imported into MIMICS and visualized.

Physical model was made from the CT data and fractured segments were reduced and the fixation plates were adapted and fixed on the 3D physical model and the same was done intraoperatively.

This reduced the operative time.

Case 6

A patient named Devi 23/F came with complaints of swelling in the left side of the face for the past two months. She was previously diagnosed to have dentigerous cyst, and multiple curettage had been done, but the swelling was reoccurring.

A complete case history was taken and blood and radiographic investigations were done.

Biopsy was done and the pathologic report was ameloblastoma.

CT was taken according to the previously said protocol and imported into MIMICS in DICOM format.

Extent of the pathology was visualized.

3D reconstruction was done with the CT data and a physical model was done.

Model surgery was done on the physical model to determine the length of resection and reconstruction plate was adapted to the model.

The pre adapted reconstruction plate was fixed to the mandible and then the pathologic segment of the mandible was resected as planned, the avoided the intra operative bending and adapting of the reconstruction plate and helped in fixing of the reconstruction plated to condyle and mandible easily thereby reducing the surgical time.

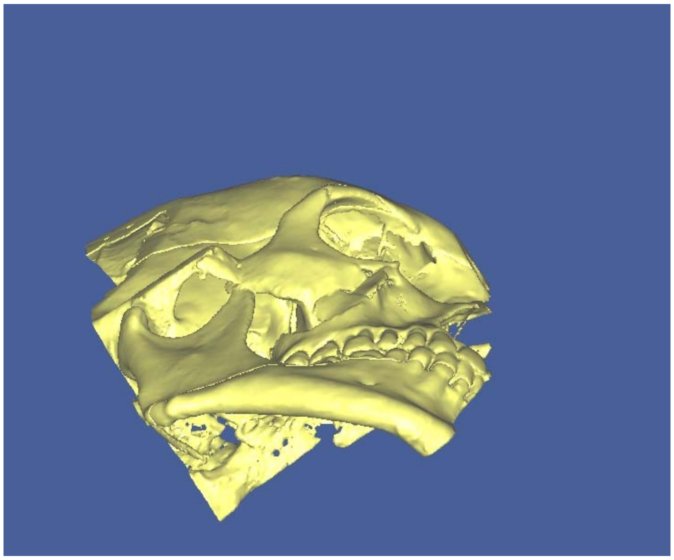
Visualization

and

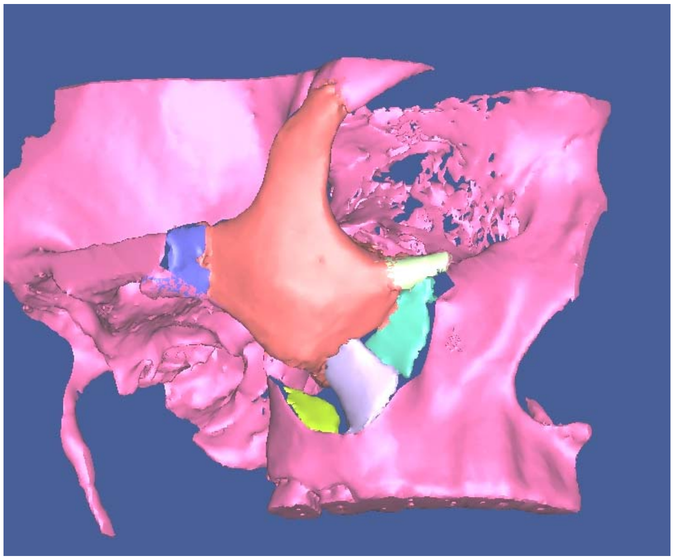
Diagnosis

Frontal view showing mild visible depression in the right zygomatic arch region.

Right side arch depressed



Restriction of the coronoid visualized in the virtual 3D reconstruction



Elevation reduction and fixation of all the six fractured segments was not required, and so only elevation of the zygomatic arch to improve mouth opening and elevation of the buttress region to attain fullness was done. Stable fixation at the fronto-zygomatic suture and and at the buttress alone was found to be enough to achieve the form and function.

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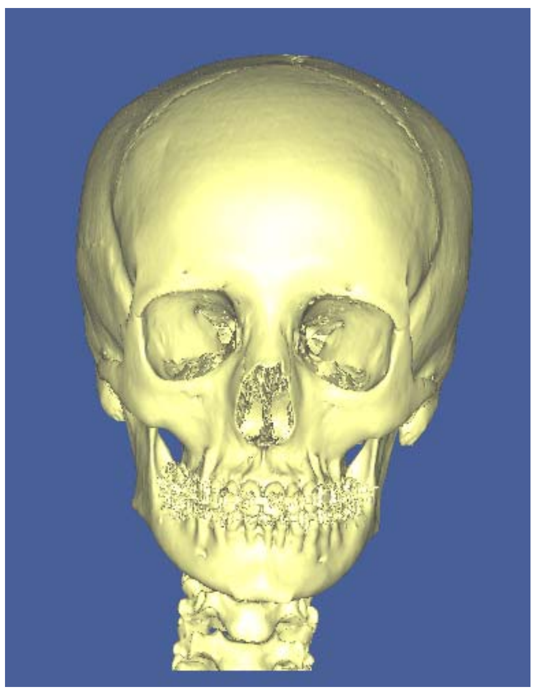
Post OP fullness in the right zygomatic arch region

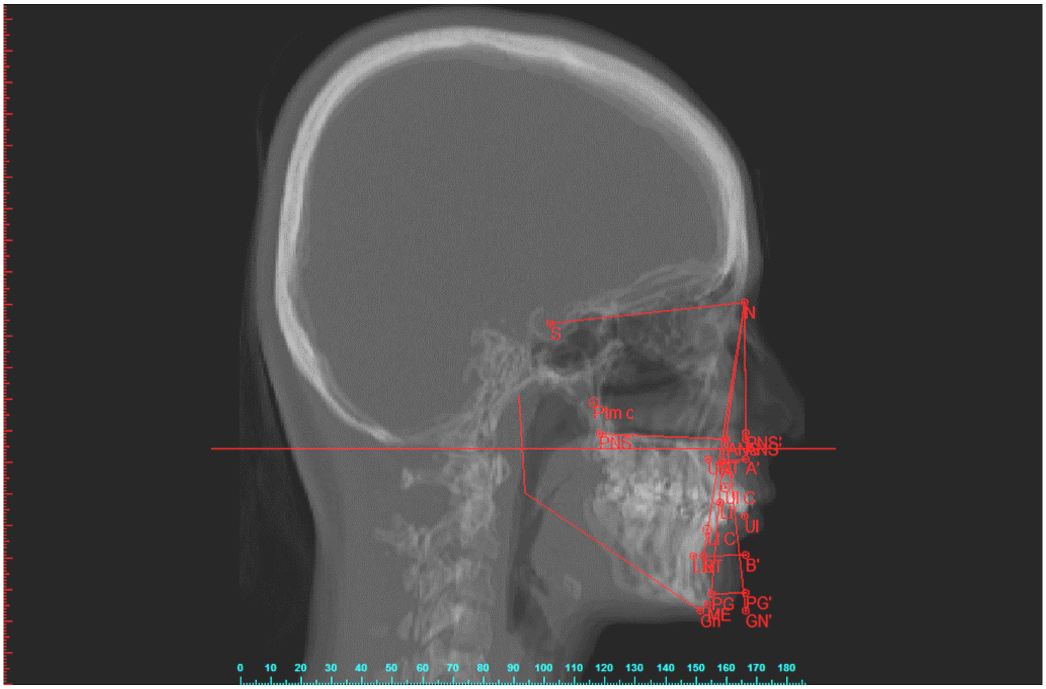
Frontal view preoperative

Pre operative Profile view

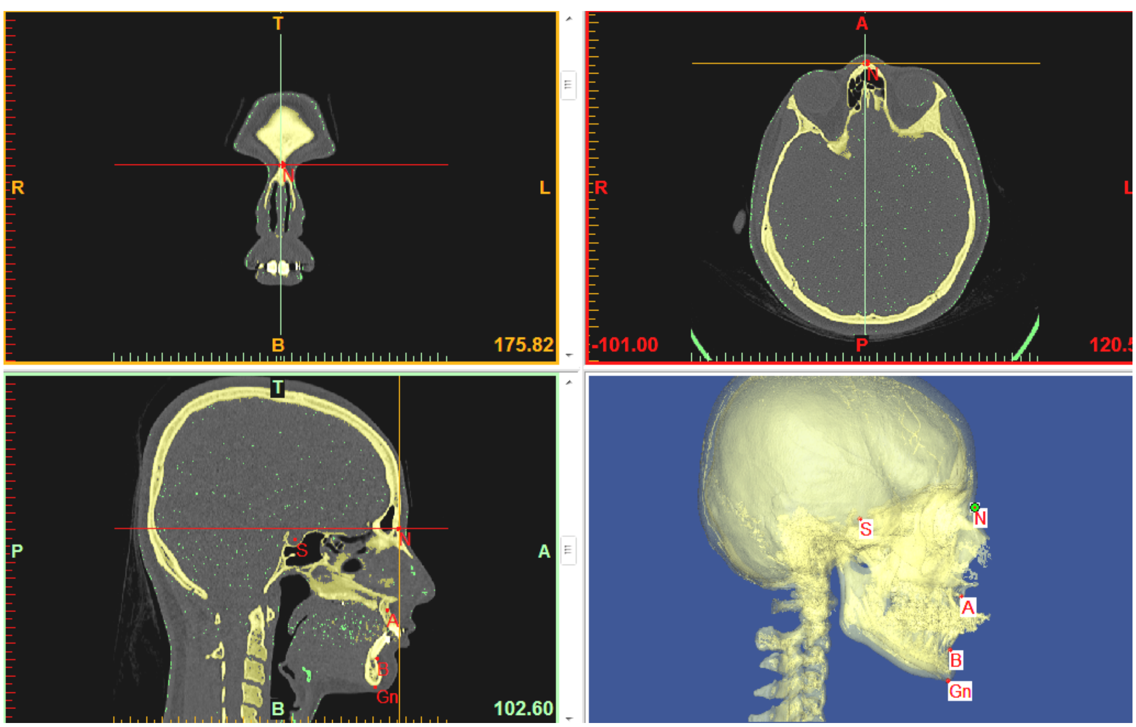
CT in the mid Sagittal section



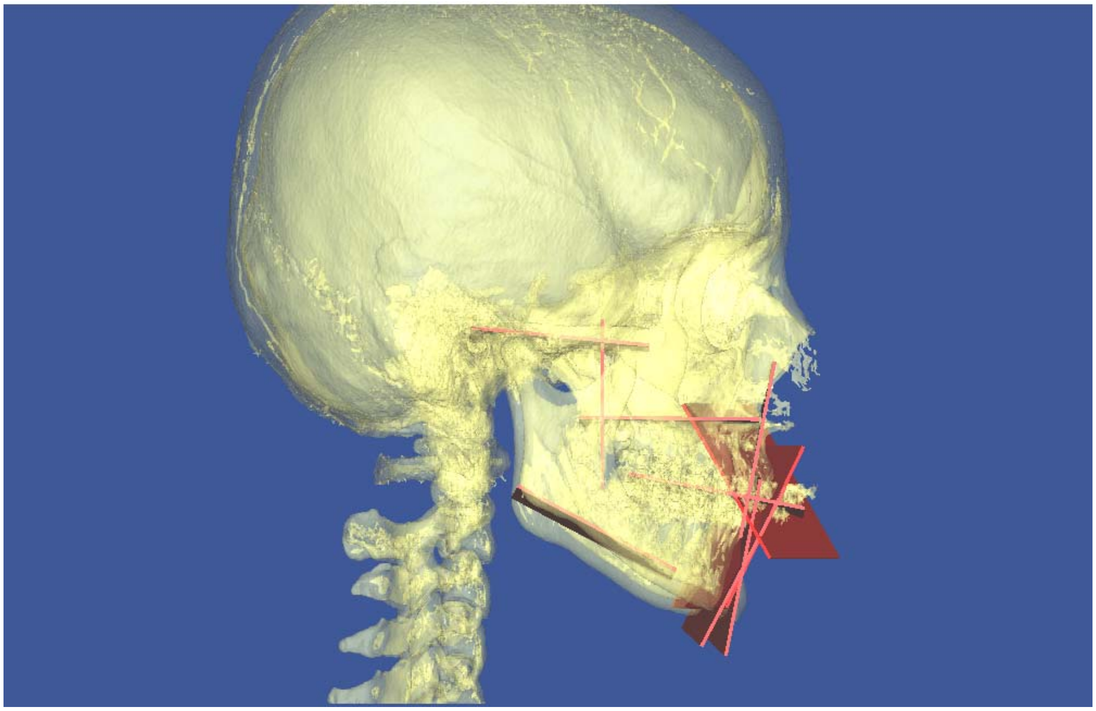
Virtual model reconstructed from the CT data



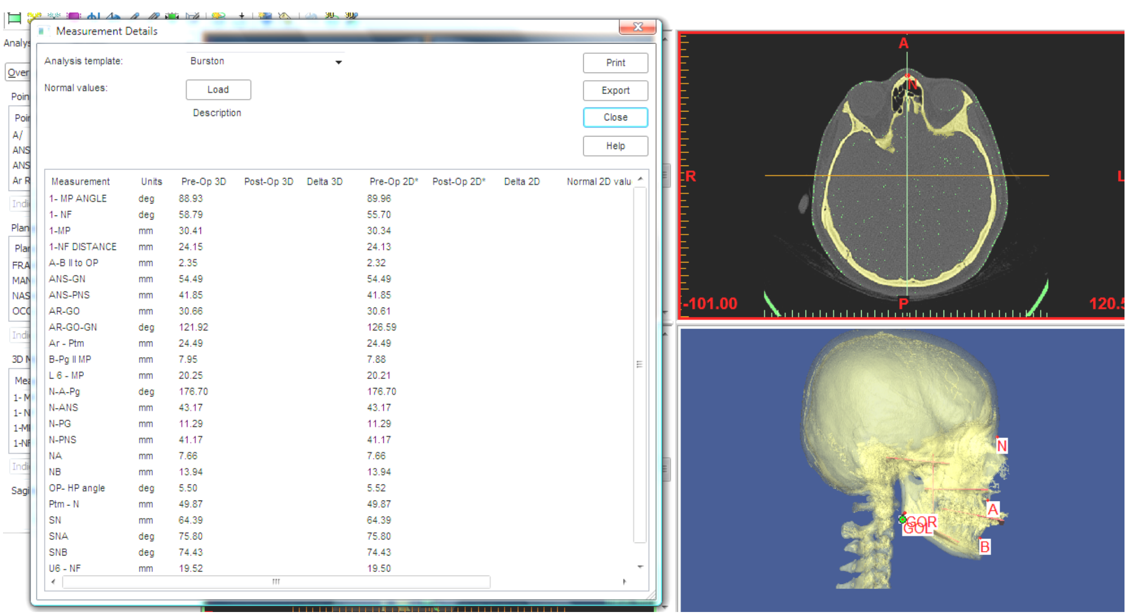
Points marked in the CT in the mid sagittal section



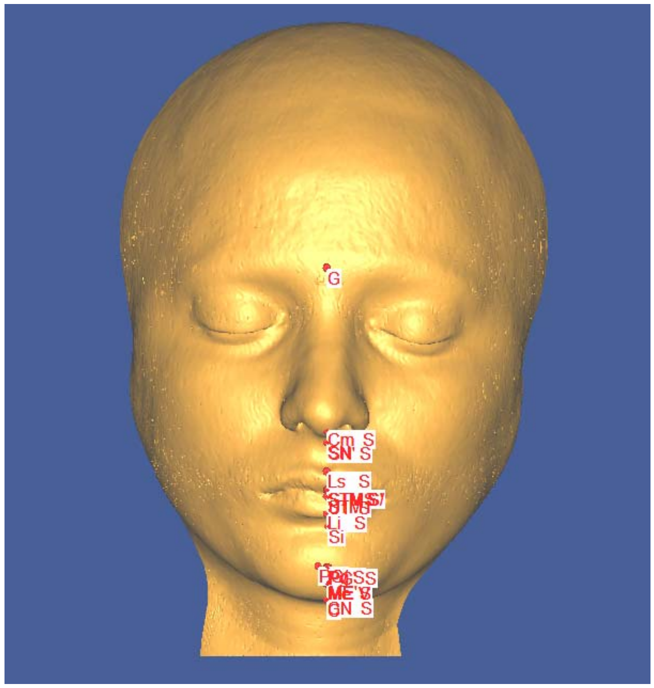
View of points on all the three sections and on the virtual 3D model



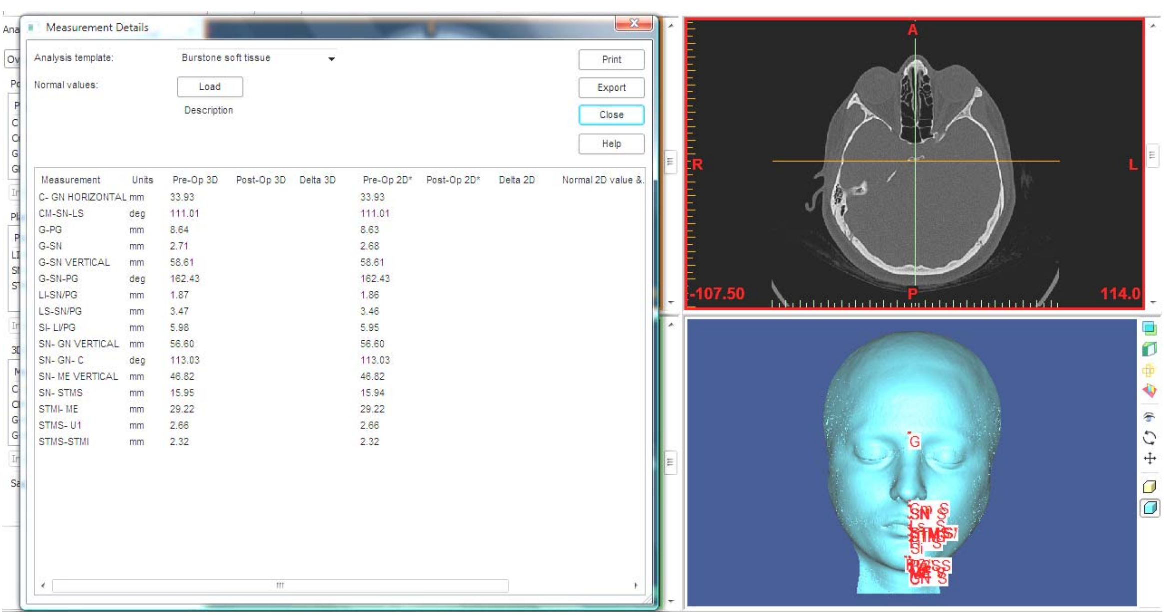
Constructed planes on the virtual 3D model



Hard tissue cephelometric values



Soft tissue Burrstone analysis



Measurement	Units	Pre-Op 3D	Post-Op 3D	Delta 3D	Pre-Op 2D*	Post-Op 2D*	Delta 2D	Normal 2D value &.
C- GN HORIZONTAL	mm	33.93			33.93			
CM-SN-LS	deg	111.01			111.01			
G-PG	mm	8.64			8.63			
G-SN	mm	2.71			2.68			
G-SN VERTICAL	mm	58.61			58.61			
G-SN-PG	deg	162.43			162.43			
LI-SN/PG	mm	1.87			1.86			
LS-SN/PG	mm	3.47			3.46			
SI- LI/PG	mm	5.98			5.95			
SN- GN VERTICAL	mm	56.60			56.60			
SN- GN- C	deg	113.03			113.03			
SN- ME VERTICAL	mm	46.82			46.82			
SN- STMS	mm	15.95			15.94			
STMI- ME	mm	29.22			29.22			
STMS- U1	mm	2.66			2.66			
STMS-STMI	mm	2.32			2.32			

Soft tissue values

Post operative Frontal view

Post operative Profile view

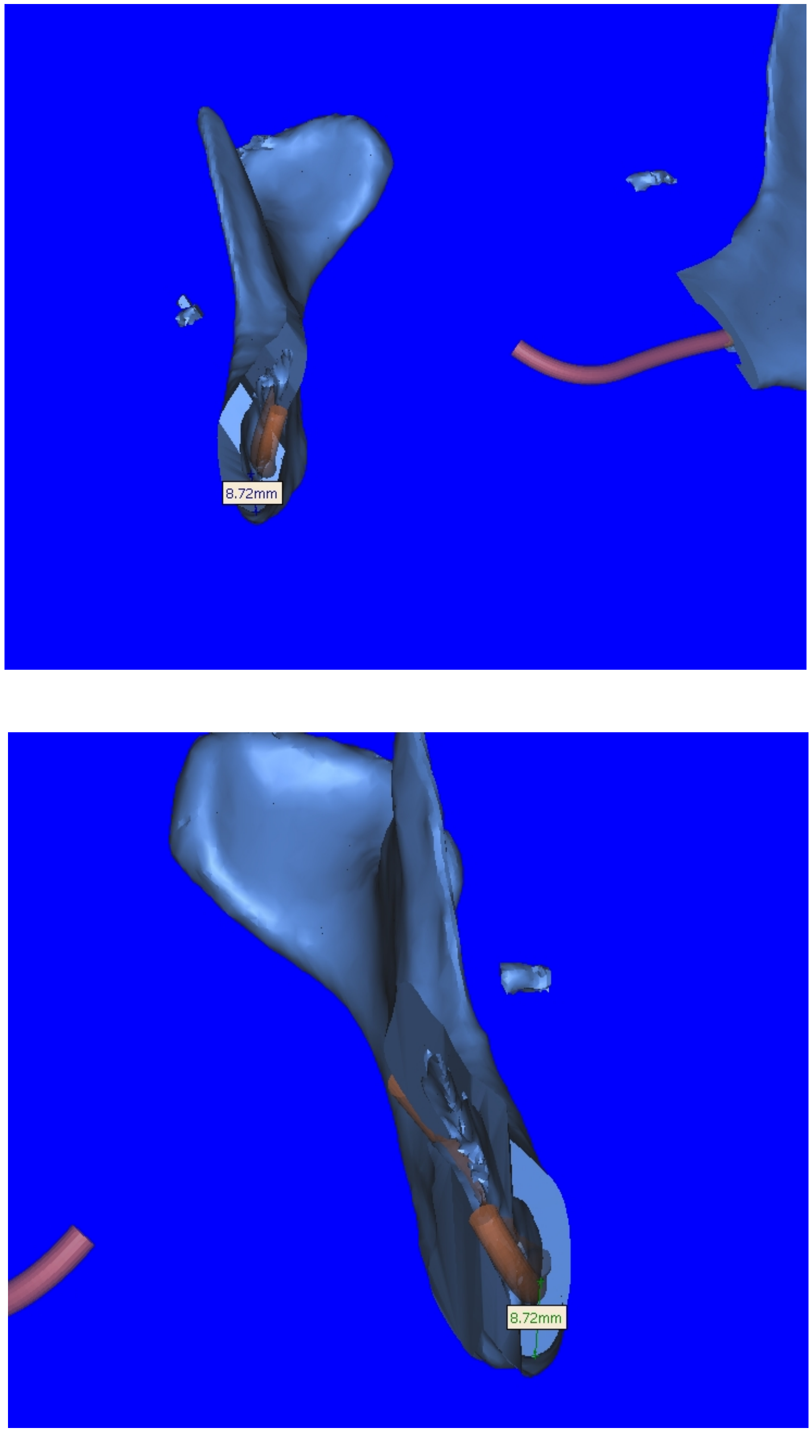
Treatment Planning

and

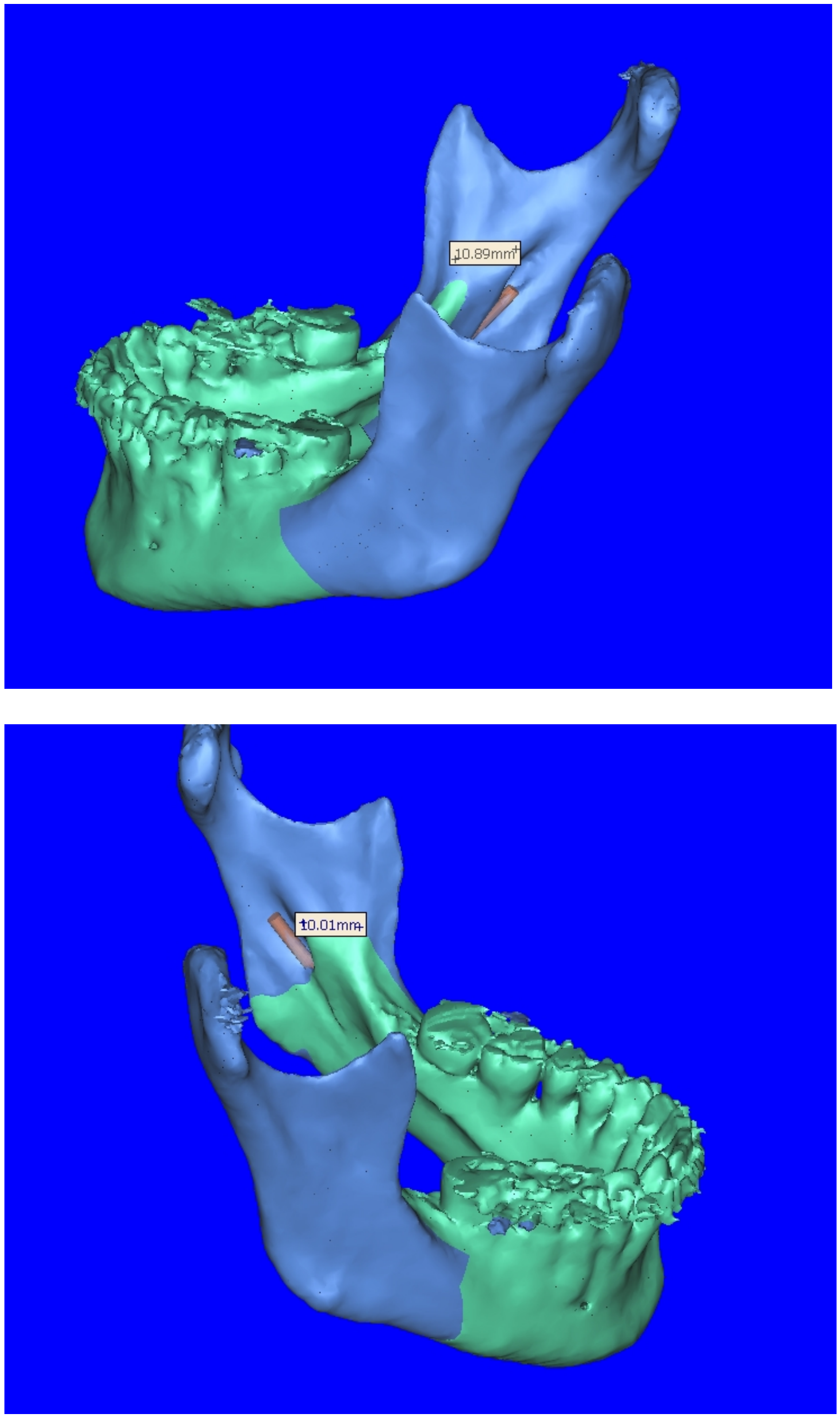
Surgical Simulation

Frontal view

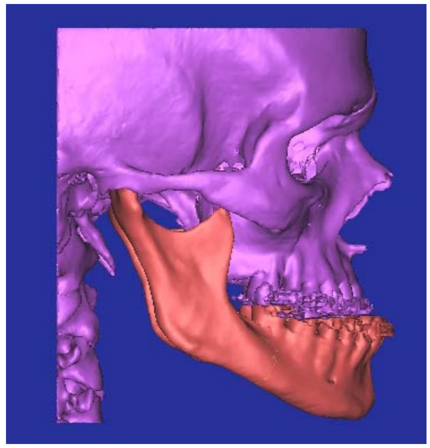
Profile view



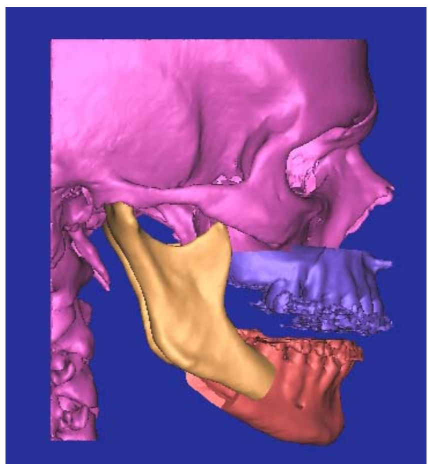
Measurements of proximity of inferior alveolar nerve to the BSSRO cuts.



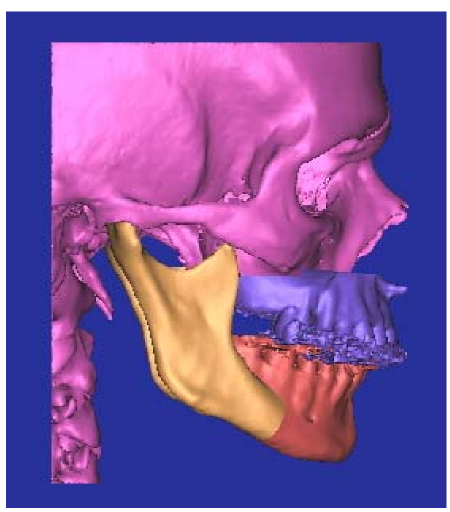
Measurements at the lingula region



Pre operative lateral view of the hard tissue



Simulation of Lefort 1 maxillary advancement and BSSRO set back.



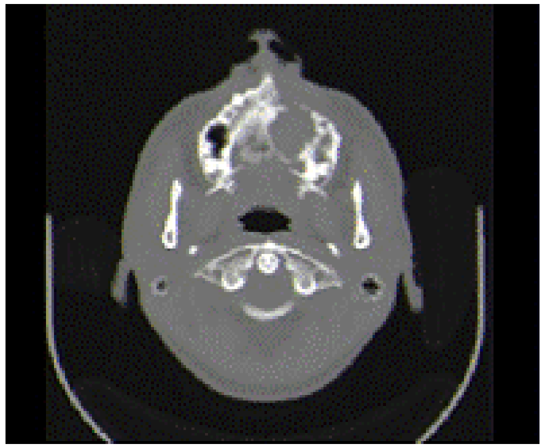
Occlusion achieved through Bilateral sagittal split osteotomy.

Postoperative frontal view

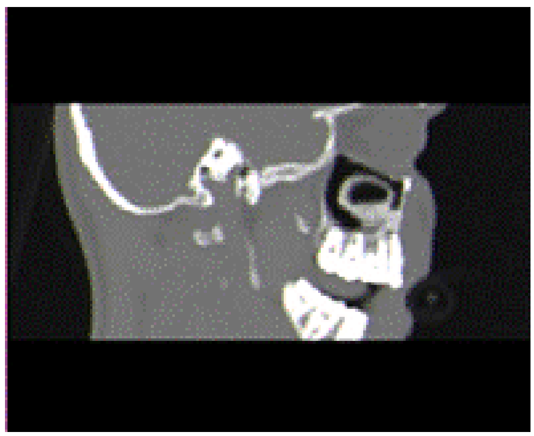
Postoperative profile view

Intra oral picture shows the swelling and ulceration in the left palate.

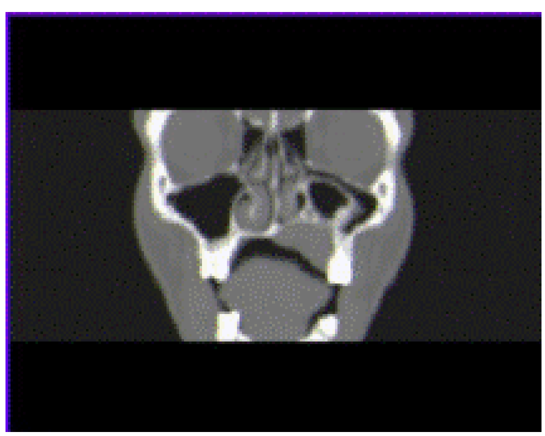
PNS Radiograph not showing a clear view of the pathology



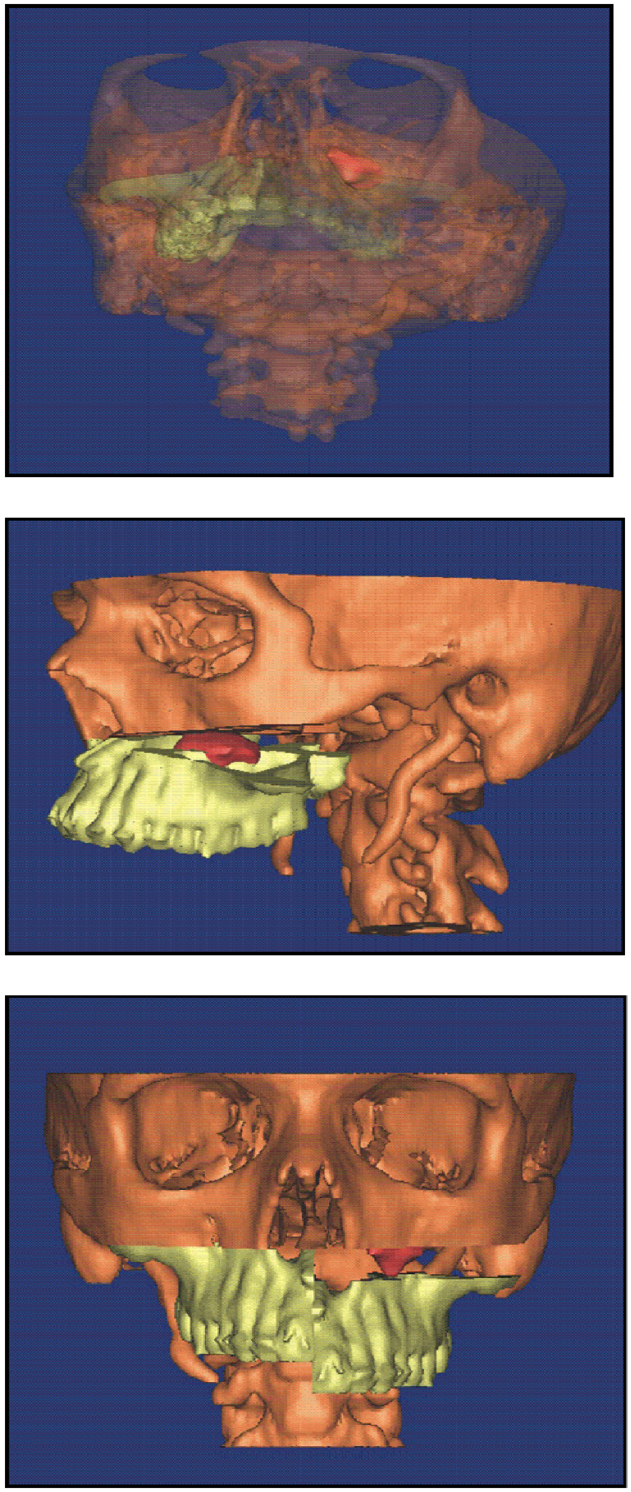
Axial section of the CT at this slice showing the medial and the lateral borders.



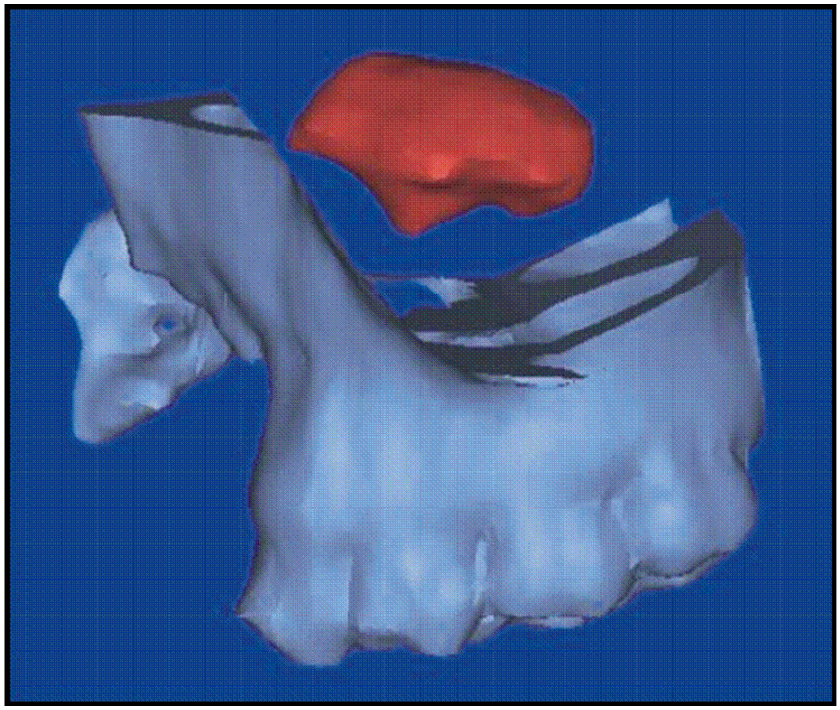
Sagittal section showing the superior and the inferior and antero posterior extent of the pathology.



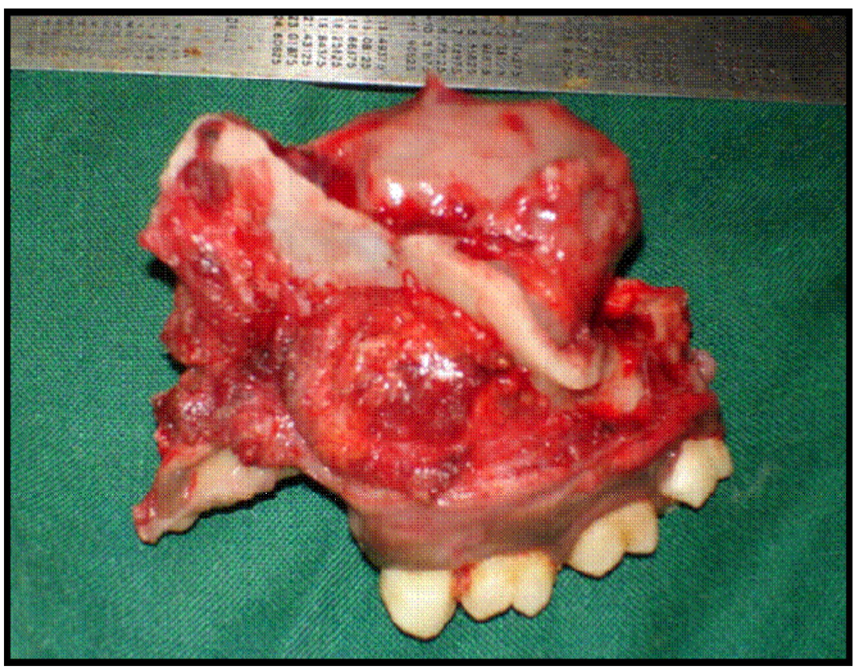
Coronal section showing clearly the inferior involvement of the palate



Virtual 3D reconstructions showing the extent of pathology



Virtual resection of pathology.



Resected specimen

Physical Model

Analysis,

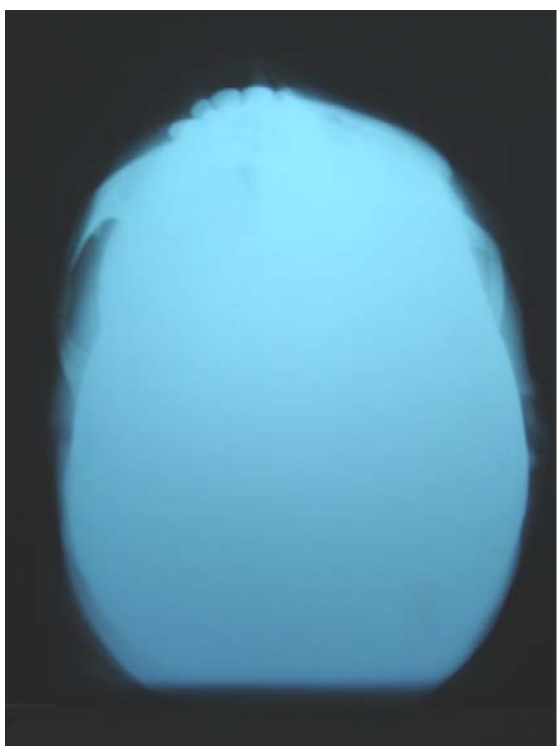
Surgical simulation and

Template preparation

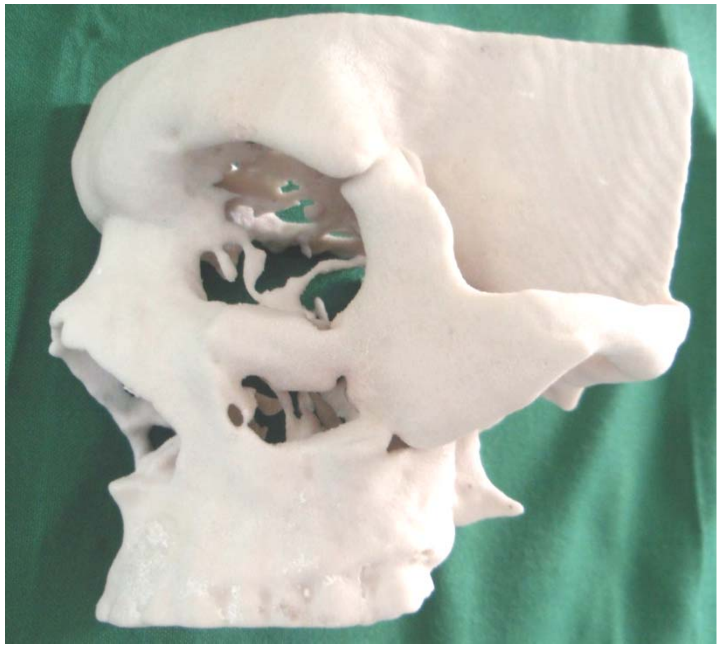
Frontal view

Lateral view

PA 10° not descriptive of the fracture



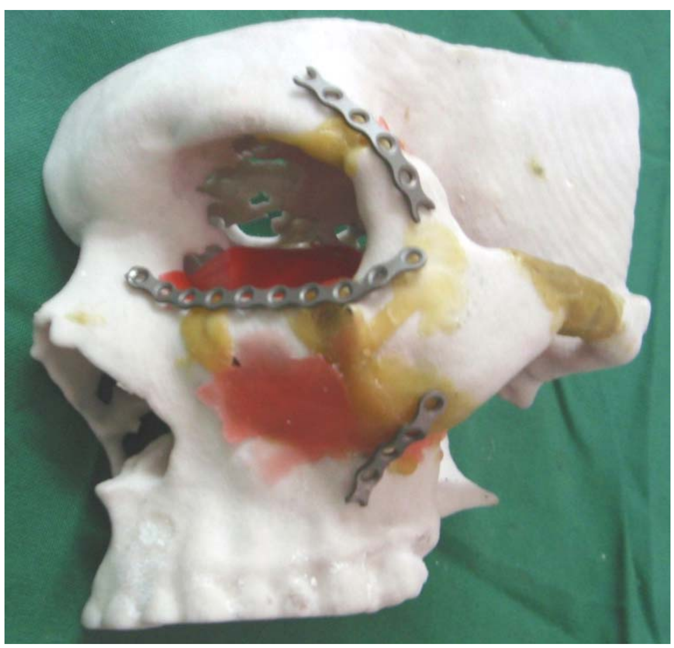
Sub Mento Vertex showing depressed left zygomatic arch



3D physical model showing extent of fracture and displacement

Fractured segments cut and removed during mock model surgery

Fractured segments were reduced and repositioned in the physical model surgery



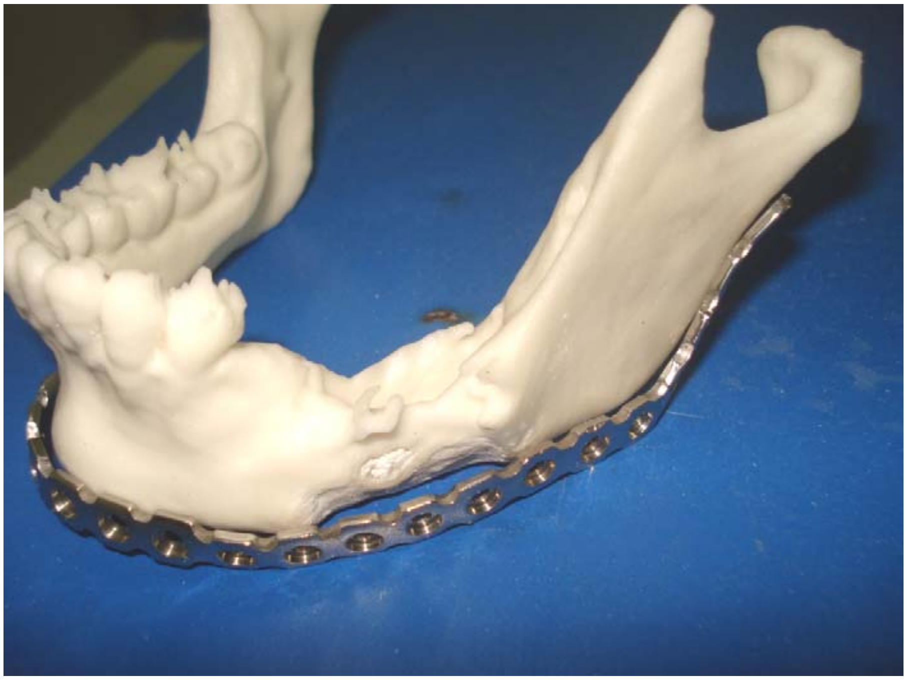
Adaptation of plates on the repositioned segments was done and the same plates were sterilized and used intraoperatively.


Intra operative use of preadapted plate.


Postoperative frontal view

Frontal view

3D model showing extent of involvement of mandible by the tumor.



Adaptation of reconstruction plate to the physical model

Intraoprative fixing of preadapted plate before resection of the mandible

Reconstruction plate in position after resection of the mandibular segement.

Post operative

DISCUSSION

History of CT scan

The theory of image reconstruction from projections, which is central to the basic concept of CT, was described in 1917 and was proposed for medical imaging as early as 1940. The development of the first modern CT scanner was begun in 1967 by Godfrey Hounsfield, an engineer at British EMI Corp. the first clinical CT scanner was built and installed at Atkinson-Morley Hospital in England in September 1971.

First generation CT scan

The x-ray tube is rigidly linked to an x-ray detector located on the other side of the subject. Together, the tube and the detector scan across the subject, sweeping the narrow x-ray beam through the slice.

Thus the x-ray tube scans in a linear motion across the patient, after completing a linear scanning, the tube and the detector set is rotated around the patient by 1° and this rotation is done till 180°. Thus in one linear slice, the x-ray tube scans the same subject in 180°. The combination of linear translation followed by incremental rotation is called translate–rotate motion. Data collection was accomplished with a single narrow beam and a single sodium iodide (NaI) scintillation detector. This arrangement which is single detector and single narrow beam with translate–rotate motion is referred to as first-generation CT.[28]

Second generation CT scan

A step toward reduced scan times was taken with the introduction of second-generation CT geometry in late 1974. Second-generation CT used multiple narrow beams and multiple detectors and, as in the first generation, used rotate–translate motion. If 3 x-ray tube and 3 detectors were used then the time consumed was 3 times lesser compared to the first generation CT scanners.[28]

Third generation CT scan

Faster scans required the elimination of translation motion and the use of smoother and simpler pure rotational motion. This goal is accomplished by widening the x-ray beam into a fanbeam encompassing the entire patient width and using an array of detectors to intercept the beam. The detector array is rigidly linked to the x-ray tube, so that both the tube and the detectors rotate together around the patient, a motion referred to as rotation–rotation.[28] Many detectors are used to allow a sufficient number of measurements to be made across the scan circle. This design, characterized by linked tube–detector arrays undergoing only rotational motion, is known as third-generation geometry.

Fourth generation CT scan

By 1976, scans were achieved with a design incorporating a large stationary ring of detectors, with the x-ray tube alone rotating around the patient. This approach is known as fourth-generation geometry. With regard to sampling in fourth-generation CT, the set of rays measured by one detector as the x-ray tube sweeps across its field of view is analogous to one third-generation fanbeam view but with the roles of tube and detectors reversed. Each fourth-generation detector collects a complete fanbeam view which may be rebinned into parallel-ray views, but a view in which sample spacing may be arbitrarily close, limited only by how rapidly measurements are made as the tube sweeps across the field of view of the detector. Also, unlike third-generation detectors, each fourth-generation detector can measure rays at any distance from the center of rotation and can be dynamically calibrated before it passes into the patient's shadow, so that ring artifacts are not a problem. On the other hand, the number of detectors strictly limits the number of views that can be acquired [28].

Slip Ring Scanners and Helical CT

After the fourth generation, CT technology remained stable until 1987. By then, CT examination times were dominated by interscan delays. After each 360° rotation, cables connecting rotating components, x-ray tube and, if third generation, detectors, to the rest of the gantry required that rotation stop and reverse direction. Cables were spooled onto a drum, released during rotation, and then respooled during reversal. Scanning, braking, and reversal required at least 8–10 s, of which only 1–2 were spent acquiring data. The result was poor temporal resolution and long procedure times. Eliminating interscan delays required continuous nonstop rotation, a capability made possible by the low-voltage slip ring. A slip ring passes electrical power to the rotating components e.g., x-ray tube and detectors, without fixed connections. The idea is similar to that used by bumper cars; power is passed to the cars through a metal brush that slides along a conductive ceiling. Similarly, a slip ring is a drum or annulus with grooves along which electrical contactor brushes slide. Data are transmitted from detectors via various high-capacity wireless technologies, thus allowing continuous rotation to occur. A slip ring allows the complete elimination of interscan delays, except for the time required to move the table to the next slice position. However, the scan-move-scan sequence known as axial step-and-shoot CT) is still somewhat inefficient.[28]

Multi slice CT scan

In the multi slice CT, the x-ray beam is wider and is detected by an array which is many lines of detectors placed next to each other, thereby allowing the generation of more slices during one rotation[22,28]. There are now multislice scanners that can generate at the same time 16 or 32 or 40 or 64 slices. Newer ones that can generate 256 slices. Another major difference from single slice CT scanners is that the x-ray can be kept on while the patient table is moved. This also increases the speed of scanning the patient.

MedCAD software

CAD software, also referred to as Computer Aided Design software and in the past as computer aided drafting software, refers to software programs that assist engineers and designers in a wide variety of industries to design and manufacture physical products ranging from buildings, bridges, roads, aircraft, ships and cars to digital cameras, mobile phones, TVs, clothes and of course computers. CAD software is often referred to as CAD CAM software 'CAM' is the acronym for Computer Aided Machining.

Now CAD softwares are also used in the medical field to virtually or physically build the CT data which is acquired in the DICOM format.

Although computers were virtually error-free, glitches in programming or the interface problems occasionally resulted in unforeseen and usually costly scrap. Once again technology came to the rescue. Connecting a television monitor to the computer allowed graphing data to a visual image of the finished part. Errors were easily seen and corrected. Other manufacturing executives and engineers noticed the cost savings in time and material.

Today architects, mechanical engineers, electronics engineers, civil engineers, interior designers, even artists utilize CAD to assist their design process to visualize their final design in real-time animated 3D space. Data from CT scans can be converted to CAD data which enables doctors with the unique opportunity to view patients' internal organs. The rapid prototype model obtained from the virtual CAD object enables in doing physical surgical simulation on the physical model.[4,16]

MIMICS

Materialise's Interactive Medical Image Control System (MIMICS) is an interactive tool for the visualization and segmentation of CT images as well as MRI images and 3D rendering of the data into virtual object and then for obtaining physical model . Therefore, in surgery Mimics can be used for diagnostic, treatment planning or simulation of surgical procedure. These virtual surgical simulations and the templates from the CAD software can be exported in a suitable format and physical models can be obtained.[6,8]

The software enables the user to control and correct the segmentation of CT-scans and MRI-scans. For instance, image artifacts coming from metal implants can easily be removed. The objects to be visualized and/or produced can be defined exactly by the surgeon. No technical knowledge is needed for creating on screen 3D visualizations of required objects like maxilla, mandible etc.

The various modules in this software are useful in visualization, measurement and analysis and simulation.

In visualization, we can threshold the different structures in the CT like bone, compact and, medullary. In soft tissue muscle, fat, skin can be visualized and threshold of enamel also can be done and a mask can be made and edited which can be converted into a 3D virtual model.

The tools available in this software help in measuring, linear lengths,[59] angles in both 2D and 3D. Bone density in a selected region can also measured in Hounsfield units. It is also possible to draw nerve in its position and measure and manipulate it.[3,29,41,57]

In the simulation part this software has wizards like osteotomy wizard and distraction wizard. Using osteotomy wizard it is possible to do virtual orthognathic surgeries. Reposition tool helps in repositioning the cut segment in the desired position, Mirroring tool helps to create a exact replica of any structure from one side to another side and merged when reconstructive surgeries are planned. Distraction wizard performs the osteotomies and distraction can be simulated which helps in planning the amount of distraction placement and position of distractors and their vectors.[2,8,12,14,64]. Distractor library is present which enables us in choosing from various distractor models and companies. Boolean operations perform an addition or subtraction operations between two different masks. We can also measure and analyze the various cephelometric analyzes that are present by default. A customized cephelometric analysis can also be configured.[27,36]

FEA Finite Element Analysis module is also an additional feature in this software which helps in prediction of outcome of surgery in relation to function.[33]

Mimics is a general-purpose segmentation program for gray value images. It can process any number of 2D image slices. It requires powerful processor and large physical memory of the computer and dedicated graphics card.

Physical model

Rapid prototyping

Physical model is nothing but a prototype of the object or the material which is under consideration and in the medical field it can be a skull or any bone which is to be treated. Rapid prototyping is done with a software package which "slices" the CAD model into a number of thin ~0.1 mm layers, which are then built up one atop another. Rapid prototyping is an "additive" process, combining layers of paper, wax, or plastic to create a solid object. In contrast, most machining processes which are milling, drilling, grinding, etc. are "subtractive" processes that remove material from a solid block. RP's additive nature allows it to create objects with complicated internal features that cannot be manufactured by other means.[21,23]

Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are:

1. Create a CAD model of the design
2. Convert the CAD model to STL format

3. Slice the STL file into thin cross-sectional layers (Reslicing)

4. Construct the model one layer atop another

5. Clean and finish the model

The various Rapid Prototyping Techniques are

1. Stereo Lithography (SLA)
2. Laminated Object Manufacture (LOM)
3. Selective Laser Sintering (SLS)
4. Fused Deposition Modeling (FDM)
5. Solid Ground Curing (SGC)
6. 3-D Ink Jet Printing

CASE DISCUSSION

Visualization and Diagnosis

Case 1

A case of trauma to the right zygoma due to sports, hit by a cricket ball, following which he complains of mild depression in the malar region and decreased mouth opening.

After importing the CT data into the software using the visualization module, bone thresholding was done and a 3D virtual model of the skull with the mandible was created. This virtual model can be viewed from any angle in all 360° of rotation. This helps to view the nature of fracture that has occurred, the amount of displacement, number of fragments and the bones involved.[10.19,23,56]

In this case we found that the buttress region was fractured into 6 segments including the fracture of the zygomatic arch into three fragments. We analyzed the nature of fracture of the zygoma to be depressed around the horizontal axis superiorly outwards with separation of the frontozygomatic suture and inferiorly inward with the buttress region in 5 fragments. With this available information from the 3D visualization we decided that elevation of the zygomatic arch with a stable fixation of the frontozygomatic suture and one rigid fixation of the lower most fragment of the buttress region was sufficient to improve the mouth opening and give fullness to the cheek. This helped in avoiding fixing of all the fractured segments which was unnecessary, doing which would have only increased intraoperative time[39] and increased hardware in the patient, with no better outcome to the result we have achieved now.

Case 2

A case of mandibular deficiency. Advancement of mandible by bilateral sagittal split osteotomy was planned.

The simulation module of the software has measure and analyse tool where various analyses done for orthognathic surgery are available. This tool also allows us to configure a new analysis and we programmed burrstone lateral cephelometric analysis into this tool for both hard and soft tissue. This helped to analyse this patients pre operative values of both hard and soft tissue and come to a diagnosis and treatment plan. BSSRO advancement was planned and virtual simulation was done to predict the outcome of the planned surgery. Soft tissue changes to the surgery were also visualized and this helped in explaining the patient and the parents about the possible outcome of the surgery.[1,6]

Treatment planning and Surgical simulation

Case 3

A case of maxillary deficiency for whom orthognathic surgery of lefort1 advancement combined with bilateral sagital split osteotomy to set back was planned.

Using the osteotomy wizard,[41] three options were tried. Adavancement of maxilla alone, setback of mandible alone and advancement of maxilla with set back of mandible. It was decided the third option was the best for the patient and the osteotomy cuts were done for both maxilla and mandible. The osteotomised segments were then repositioned using the repositioning tool. This helped in determining the amount of maxillary advancement and mandibular sertback.[13,41]

Using the visualization module in the software 3D view of the mandible was acquired. This module has a tool which enables drawing of nerve[13] by which a nerve can be simulated in its original position in the mandible. The inferior alveolar nerve was simulated in the canal and visualized. This software also has tools to measure 2D and 3D lengths. We used this tool to measure the distance of inferior alveolar nerve from buccal cortex, from the inferior border, from the superior border, from anterior border of the ramus to lingual and from the sigmoid notch to the lingual in relation to region of the mandible where the osteotomy was planned to be performed. These measurements gave us information about the position of nerve in relation to the osteotomy which helped in avoiding injury to the inferior alveolar nerve.[13,62]

Case 4

A patient diagnosed with mucoepidermoid carcinoma of left maxillary sinus, for whom we used this software to visualize and do virtual surgical simulation of resection of tumor. PNS radiographs and OPG was not specific enough about the extent of pathology and so we decided to take CT for this patient.

With the importation of the patients CT data the virtual 3D model of the skull was constructed and we were able to visualize the extent of pathology. From the reconstruction and CT images in the three planes we found that the tumor was confined within the maxillary sinus and had involved the left palatal bone and had not involved the lateral nasal wall or the floor of the orbit. We decided to do a partial maxillectomy with the involved palalatal soft tissue. Virtual surgical simulation of the resection was done which helped to decide the exact location of osteotomy and the structures to be resected.[10,19,41] With this preavailable surgical plan the intraoperative time[39] was very much reduced as there was no need for visualizing the extent of tumor invasion and decision making about the extent of resection intraoperatively.

Physical model- Analysis, Surgical Simulation and Templates

Case 5

A case of road traffic accident, with trauma to left zygomatic complex. We used the CT data to reconstruct the virtual model and visualized the fracture. The frontozygomatic suture, zygomatic arch, zygomatic buttress of the left side were fractured. To elevated the depressed cheek and improve the mouth opening the fractured segments had to be reduced and fixed. The software allows exporting the reconstructed object in suitable language (STL) from which physical models can be obtained by rapid prototyping technique. We acquired a rapid prototype model of this patients left side of the skull and physically cut and reduced the fractured segments.[23] Sticky wax was used to align and hold the reduced fragments. After reducing the segments we adapted the fixation plates to the bone contour on the physical model, [23] which were sterilized and used intraoperatively to fix the reduced segments. Since we had reduced the fragments in the physical model, surgical orientation intraoperatively[39] was much better and preadapted plates reduced the intraoperative plate bending time.

Case 6

A case of ameloblastoma of the left side of the mandible, and the 3D reconstruction was useful in knowing the extent of the pathology which helped us in deciding the amount of resection of mandible. Physical model of the mandible was made and we planned to do partial resection of the mandible leaving behind the condyle and some length of ramus in the posterior region near the condyle to fix the recinstruction plate.[23] Reconstruction plate of the desired length was selected and adapted to the mandible and sterilized. Intraoperatively the mandible was exposed and before performing the resection the preadapted plate was fixed to the posterior part of left condylar neck and the right symphysis region as previously planned in the physical model. Then the resection was performed. This allowed for a anatomically stable reconstruction of the mandible without effecting any change to the condylar position of both the condyles and a better facial contour as the reconstruction plate was adapted to the physical model of the patients own mandible. The intraoperative time was reduced,[23,39] the esthetics and function attained as a result of the surgery planned with this software was very much appreciated by the surgeon and the patient.

CONCLUSION

The data produced by the CT machines are a series of images. These images are printed on sheets and are viewed as conventional 2D images only and are not interactive. But through this software the CT data is now very interactive.

A powerful processor, large virtual memory of the computer and dedicated graphics card is required.

This software provides a better visualization of the anatomy and pathology, compared to conventional CT images.

Accurate measurement between points and measuring of angles is possible with this software.

Osteotomy, distraction and other surgical simulation can be done with this software.

Splints templates and guides for intraoperative use can be fabricated.

This software eliminates cumbersome procedures to the patient like facebow transfer and impression making.

It is a good learning tool as it gives exact details of the anatomy.

From this study we conclude that MIMICS a medical based CAD software is a very efficient tool in Visualization, Diagnosis, Treatment planning, Surgical Simulation and fabrication of Templates for intraoperative use in Oral and MaxilloFacial Surgery.

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